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AGRICULTURAL
EXPERIMENT STATION



FIELD EXPERIMENTS ON
BUNT OF WHEAT

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FIELD EXPERIMENTS ON BUNT OF WHEAT

BY G. H. STARR

INTRODUCTION

Losses from bunt or stinking smut of wheat are caused by two types of organisms: The smooth spore (*Tilletia levis* Kuhn) and the rough spore (*Tilletia tritici* (Bjerk) Wint.), shown in Figures 1 and 2, respectively. The various stages in the germination of these bunt spores are shown in Figure 3. Heads of wheat infected with these two organisms are very similar in appearance and cannot be accurately differentiated except by spore examination under a microscope. The front cover page shows bunted (left) and healthy (right) heads of wheat, together with the bunt balls and normal kernels of wheat.

The smooth-spored type is the one commonly found in Wyoming; in fact, the rough-spored type, as yet, has been found only

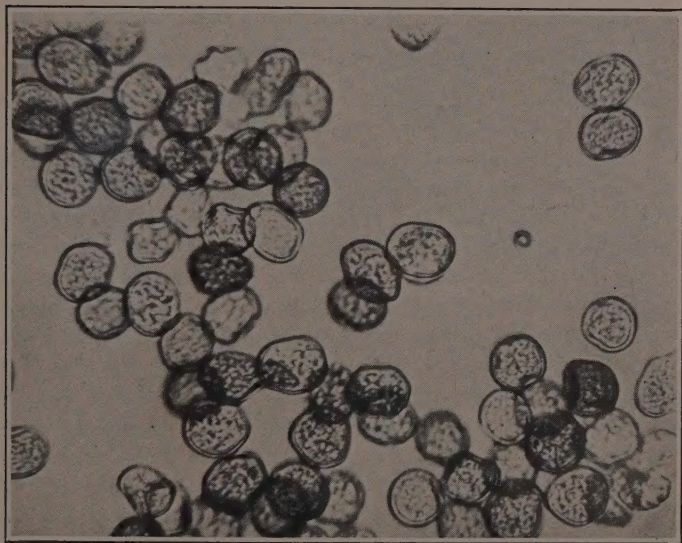


Figure 1. Spores of bunt, (*Tilletia levis*) of the smooth type, magnified about 550X.

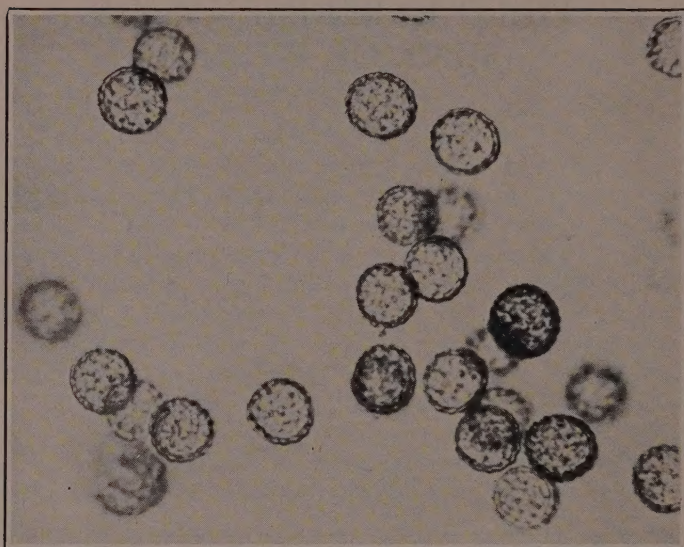


Figure 2. Spores of bunt, (*Tilletia tritici*) of the rough type, magnified about 550X.

once by the writer, although a thorough survey has not been made in all of the wheat-growing areas.

Seed treatments are recommended for the control of bunt, and it is estimated that they are used by approximately 50 to 60 per cent of the wheat growers in the state. Copper carbonate is probably the most popular treatment, although some growers use formaldehyde and some still use copper sulfate. Only a small percentage of the cereal growers now use the New Improved Ceresan, but it is gaining in popularity in the state.

Bunt varies a great deal in prevalence, from traces in some fields to about 90 per cent in the worst one observed. Such high percentages of bunt are found in fields where no seed treatment has been used, for when seed is properly treated very little bunt is likely to result. While the average loss from bunt probably is not more than 1 or 2 per cent of the crop, this, in terms of bushels of wheat, would be an appreciable loss. The average production of spring wheat in Wyoming for the years 1924 to 1935,

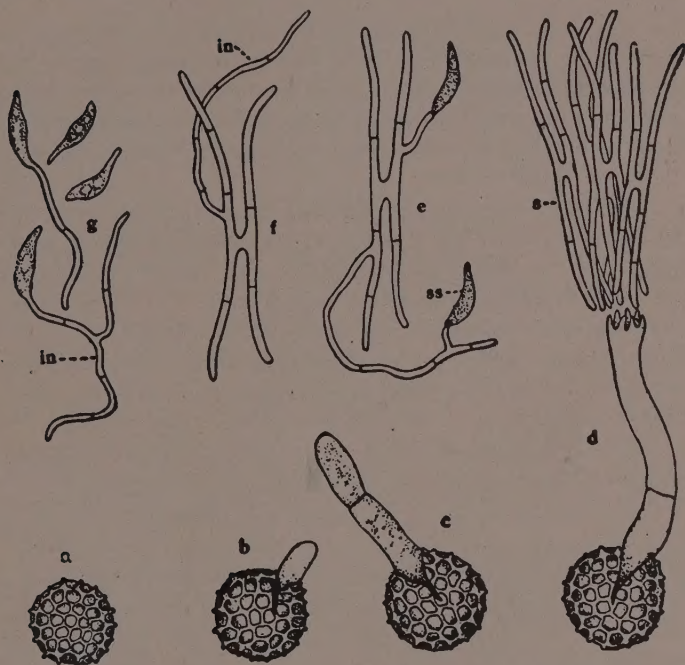


Figure 3. Various stages in the germination of spores of stinking smut (*Tilletia tritici*). a, spore surface showing characteristic reticulate ridges; b, c, stages in the formation of the promycelium; d, mature promycelium with terminal fascicle (s) of H-shaped sporidia; e, a separated sporidium which has germinated to form secondary sporidia (ss); f, a separated sporidium which has given rise to an infection thread (in); g, several secondary sporidia which have started to germinate and have produced infection threads. (After Heald, Washington Exp. Sta. Bul. 126.)

inclusive, was 1,397,000 bushels. The highest production during that period was in 1928 with 3,284,000 bushels and the lowest was in 1934 with 593,970 bushels. During the same period the production of winter wheat averaged 1,172,476 bushels, the highest production being in 1930 with 2,015,800 bushels and the lowest in 1934 with 415,726 bushels.

Most of the wheat is grown under dry-land conditions, although a small acreage is irrigated. During the period, 1924-1935 inclusive, 2.9 per cent of the winter wheat and 21.0 per cent of the spring wheat was grown under irrigation.

NATURE OF INVESTIGATIONS

The experimental work conducted by the writer during the period 1932 to 1936, inclusive, may be divided into three major divisions: (1) seed treatments for the control of bunt, (2) date of planting and its relation to bunt, and (3) the effect of moisture on the prevalence of bunt.

The seed-treatment experiments were conducted on the Agronomy Farm of the Wyoming Experiment Station at Laramie, and on the Archer and Torrington state farms, although not every year at the Archer and Torrington farms. Archer is a dry-land farm, while Torrington and Laramie are irrigated ones. The date-of-planting tests were conducted only on the Agronomy farm because of inconvenience and impracticability of conducting these tests at the other places, as were the irrigation experiments.

As this experimental work is of a varied nature it will be treated separately under the headings previously mentioned.

The data presented in the tables are summarized according to the variance method as outlined by Snedecor,* the value of z at the 5 per cent point being taken as the criterion for significance of the experiments. The standard error of the difference between two means was determined and this number then multiplied by the appropriate value for t , as given in Fisher's tables, to determine the value necessary for significance.

For the benefit of those not familiar with statistical methods, a brief explanation follows concerning "significant" differences. The replications or like treatments of such experiments as these are found to vary considerably because of a number of factors, such as soil differences, variations in the methods used in caring for and harvesting, as well as other unknown or accidental "error" which often creeps in, such as injury to plants by cultivation and destruction of plants by birds, rodents, etc. All of these types of variation within a treatment, as shown by the replications, are termed "error" and are used in comparison with the differences between treatments. The differences between treatments must be larger than those within the treatments to be "significant."

*Snedecor, G. W. Calculation and Interpretation of Analysis of Variance and Covariance. Collegiate Press, Inc., Ames, Iowa, 1934.

Statistical methods determine the difference that is necessary between two treatments for one to be significantly better than the other. When a certain treatment is significantly better than another treatment, according to probability (z at the 5 per cent point) it should always be better in an average of 19 of every 20 trials.

SEED TREATMENTS

Historical. Seed treatments have been in use for many years and are considered as a standard practice for cereal growers. There are two general types of treating materials, the liquid and the dust compounds. The liquid type includes formaldehyde and copper sulfate (bluestone), although in this section of the country the formaldehyde (formalin) is more commonly used. The dust type includes copper carbonate and the organic mercury compounds, such as Agrosan G, Semesan, Bayer dust, Ceresan, and the New Improved Ceresan. Ceresan and the New Improved Ceresan are the only organic mercury compounds commonly used for bunt control.

The dust type is more popular in this state than is formaldehyde. Formaldehyde is very effective in the control of bunt, but it is likely to cause seed injury and a resulting poor stand. Heald and Smith (4)* report seed injury by the use of formaldehyde and also by copper sulfate. Lungren and Durrell (9) do not recommend wet treatments because of the factor of seed injury. Bracken (1) states that formaldehyde and copper sulfate gave significantly lower yields than did copper carbonate, probably because of fall seeding in dry soil.

Flor (2) working in Washington State reports that in the later fall plantings of periodic sowing, copper carbonate (50 per cent copper) was decidedly inferior to formaldehyde solution, although in earlier plantings up to the fifth, the differences were not significant.

Heald and Gaines (5) do not recommend formaldehyde for the control of bunt in winter wheat. However, this treatment gave the best control in spring wheat. Stephens and Woolman (13) report that the injury caused by wet treatments depends up-

*Numbers in parentheses refer to citations of literature at the end of this bulletin.

on the extent of injury caused by the threshing machine. They further stated that washing the grain in clear water following the formaldehyde treatment reduced the amount of injury. Holton and Heald (6) found that washing the bunted seed was effective in reducing the spore load as well as the percentage of smut in the subsequent crop. The average percentage of bunt for the washed grain was 2.9, while that for the unwashed was 19.1.

As to dust treatments, copper carbonate is one of the older ones and has given good results in most places. The copper content varies in these dusts, being 17 to 20 per cent in some and approximately 50 per cent in others. Heald and Gaines (5) show that for heavily infected wheat (84,257 spores per grain), the 50 per cent copper carbonate was more effective in bunt control than was the 17 per cent copper carbonate, although both gave perfect control with light (7500 spores per grain) and medium (37,173 spores per grain) inoculation with smut spores.

Holton and Heald (6) also found that the 50 per cent copper carbonate gave better control of bunt than did the 20 per cent, when the dusts were applied as much as 9 months previous to planting.

One of the newer treating materials, Ceresan, and more recently the New Improved Ceresan, has been used considerably for the treatment of bunt. Heald and Gaines (5) in preliminary tests found that it was equal to copper carbonate in the control of smut. In a later paper, however, Holton and Heald (6) showed that in certain tests, Ceresan was scarcely as effective as was the 50 per cent copper carbonate, although it was equally as effective as the New Improved Ceresan. Neill (10) states that with heavy bunt infection, he got complete control with New Improved Ceresan, which was somewhat better than the Ceresan.

The lapse of time between treating and seeding is an important factor in the amount of bunt prevalence. Neill (10), working with various organic mercury dusts, states that seed might be dusted as much as 5 months previous to planting with no significant differences in degree of smut. However, Holton and Heald (6) found that Ceresan was less efficient for bunt control, when

applied 3 to 9 months before planting than when applied 3 weeks before planting. On the other hand, they found that copper carbonate was just as effective when applied 9 months before planting as when applied 3 weeks before planting.

The rate of application of dusts is also an important factor in bunt control. Lungren and Durrell (9) found that 6 ounces of copper carbonate, both the 20 and the 50 per cent, gave better control than 4 ounces; and 4 ounces, in turn, gave better control than 2 ounces per bushel, although they state that 6 ounces is in excess of what will stick to the seed. Heald and Gaines (5) found that, on the whole, Ceresan and copper carbonate, when used at the rate of 3 ounces per bushel, were not quite as effective as the maximum load of those dusts, i.e. all that would stick to the seed. Holton and Heald (6) found that the New Improved Ceresan was even more effective for smut control at the rate of 2 ounces per bushel than it was at $\frac{1}{2}$ ounce per bushel, as is recommended. However, at 2 ounces per bushel it caused a slight reduction in stand and vigor of the plants. Neill (11) working in New Zealand use copper carbonate (both the 20 and the 50 per cent) and Ceresan on wheat seed dusted at the rate of 1 part of dust to 12 parts of seed, by weight, or 40 times the usual 2 ounces per bushel. The copper carbonate had little, if any, detrimental effect on germination while the Ceresan treatment gave almost no germination.

Experimental. Experiments with treatments were conducted at the State Experiment Station, Laramie, during the years 1932-1935, inclusive, and at the Archer Station for the years 1934 and 1935. During these years the following treating materials were used on Kota wheat: Coppercarb (18-20 per cent copper), copper carbonate (50 per cent copper), formaldehyde, and Ceresan. Bunt-inoculated check plats were planted in all cases. Clean, treated seed was planted also during 1934-1935.

Previous to treating, the wheat was well coated with a collection of bunt (*Tilletia levis* race L1*) made at the Agronomy farm the previous year. The exact proportion of bunt spores to

*The physiologic race of bunt was determined by Dr. H. A. Rodenhiser, Pathologist, Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

wheat was not determined but the wheat was very much blackened by the presence of the spores.

The formaldehyde solution was made according to recommended strength (1 pint of formaldehyde to 40 gallons of water). The lots of seed to be treated were placed in cloth bags and immersed in the formaldehyde for about one minute. They were then drained and left in the bags to dry. Ordinarily this seed was planted before it was completely dried out, but this was not always possible in the plantings made on the farms at some distance from Laramie.

The dust treatments, i.e., Coppercarb, copper carbonate and Ceresan, were applied at the rate of 2 ounces per bushel for clean to moderately inoculated wheat. For heavily inoculated lots, 3 ounces of dust were used per bushel of grain. The wheat was thoroughly mixed with the dust in a tight container of one-half gallon capacity.

The treated and untreated lots were planted in rod-rows, the rows being 1 foot apart. Each treatment was replicated from 4 to 8 times. The wheat was planted with a special one-wheel hand planter, to which had been attached a funnel and tube into which the grain was dropped. The lower end of the tube extended to within a few inches of the soil and deposited the seed just back of a double shovel. The soil rolled back in over the seed and a wide wheel packed it down in the process of planting. This planter was used in all of the field experiments, so that the depth of planting, approximately 2 inches, was uniform in all cases. The depth of planting has been shown by Woolman and Humphrey (14) to be a factor in bunt prevalence. The clean wheat was planted first in all replications, followed by the bunt-treated, and lastly, the bunt non-treated.

The bunt was carefully determined in all rows and tallied on two hand tallies, one being used for total heads and the other for bunted heads. The data were recorded for each row and the percentages calculated later. The results are shown in Table I.

It will be seen that bunt in the non-treated lots of inoculated wheat was very prevalent in all tests at Laramie. At Archer, in

TABLE I

The Effectiveness of Various Treatments in the Control of Bunt (*Tilletia levis*) in Kota Wheat, Heavily Inoculated, Treated and Planted at the Laramie, Archer, and Torrington stations during the Period 1932-1935.

Place Conducted, Year and Per Cent of Bunt

Seed treatment	Laramie ³ 1932	Laramie ³ 1933		Laramie ³ 1934	Laramie ³ 1935	Archer ³ 1934	Archer ³ 1935	Torrington 1935
None	63.8	54.5e	76.7	49.9	67.8	26.0	58.1	5.0
Copper carbonate (20 per cent)	10.8	0.4	6.5	1.8	4.5	0.1	5.9	0.0
Copper carbonate (50 per cent)	....	....	....	2.8	4.3	0.0	1.6	0.5
Formaldehyde solution	0.0	0.2	0.2	3.5	0.0a	0.0	c	0.0b
Ceresan	0.9	0.4	1.7	0.0	0.8	0.1	1.5	0.0
Clean seed (treated) . .	....	....	....	....	0.0	0.0	0.4	0.0
Difference required for significance	6.2	5.8	6.3	4.9	4.1	7.4	3.5	d

1-4 replications.

2-6 replications.

3-8 replications.

a—Seed injury resulting in about a 10 per cent stand.

b—Seed injury resulting in about a 25 per cent stand.

c—100 per cent seed injury, no plants came up.

d—Only one replication of each treatment-plot.

e—Moderately inoculated with bunt.

1934, it was less prevalent and at Torrington in 1935 only 5 per cent of bunt was found in the check plats. All treatments were significantly better than the controls. In 4 of the 8 tests, the differences between treatments were not significant. Where the differences were significant, Coppercarb, except in one case, was the least effective of the treatments used. Copper carbonate (50 per cent copper) was significantly better than Coppercarb (18-20 per cent copper) in only one case. The differences between Ceresan and formaldehyde treatments were not significant in any test. However, in 3 of the 8 trials, formaldehyde treatment was followed by a severe reduction in stand. In 1935, at Archer, although there

was abundant moisture in the soil, there was no seed germination at all, probably because the treated seed was very dry when planted. The low percentage of bunt in the Archer plat in 1934 may have been caused by the extremely dry soil, and the small amount in the Torrington plat is probably because of the higher soil temperature as compared with that at the other places. Here, too, the soil moisture was excessive, being over 6 inches for the month of May.

Inasmuch as the formaldehyde solution caused severe seed injury in some of the tests, it appears that Ceresan is the better treatment to use in the control of bunt.

Soil Infestation. In these experiments over a 5-year period, there was only slight evidence of bunt infection coming from the soil. During 1934 and 1935, clean, treated seed was planted in replicate in these plats which were located on the same soil. If bunt spores could normally live over from year to year in the soil, bunt infections should have been noted, as heavily inoculated seed was planted each year in the soil and bunt was very prevalent in the matured wheat crop, which was allowed to remain on the plat until the following crop was planted.

In the moisture test of 1935 there was, however, some evidence of bunt infection coming from the soil, as clean seed, treated with Coppercarb, yielded a small amount of bunt (2.3 to 4.9 per cent). Coppercarb did not give perfect control with badly bunted seed, but it should have given better control than this with relatively clean seed, unless the infection came from the soil.

DATE OF PLANTING

The effect of soil temperature on bunt infection has a close relation to the date of planting of wheat. Hungerford (13) in 1922 obtained the highest percentage of bunt infection at temperatures from 9 to 12 degrees C. The work of Lungren and Durrell (8) in Colorado is in close agreement with this work. Woolman and Humphrey (14) found the optimum temperature for the germination of bunt spores to be between 18 and 20 degrees C. Most workers are in general agreement as to the cardinal temper-

atures for the germination of bunt spores as given by Hecke (taken from Smith 11). Those for wheat are also given and are as follows:

Germination temperatures in degrees C.

<i>Wheat</i>	<i>Bunt Spores</i>
Minimum . . . 3-4.5	slightly less than 5
Optimum . . . 25	16-18
Maximum . . 30-32	less than 25

Lungren and Durrell (8) in Colorado found that in plantings of wheat made October 1, 14, and 30, there was 9, 14, and 48 per cent of bunt, respectively. Heald and Gaines (4) found that in periodic plantings made from August to November, the percentages of bunt were low in those made during August or early September, highest in those made during the early part of October and low to none in plantings made during late October and November. Smith (11) using the Hope and Jenkin varieties of wheat found that in five periodic fall plantings from October 29 to November 26, bunt progressively decreased with the later plantings, there being an average of 45.7 per cent of bunt in the early planting of Hope and 4.0 per cent in the late one. The Jenkin variety had an average of 95.3 per cent of bunt in the early planting and 8.0 per cent in the late one. In the four spring periodic plantings of Hope wheat from March 14 to April 7, bunt infection was very low and decreased somewhat in the later plantings. However, with the Jenkin variety, bunt prevalence did not decrease with the subsequent plantings. Flor (2), using seed of wheat hybrid 128, inoculating it with both species of bunt and planting it in ten periodic fall plantings from September 12 to November 10, found the least bunt in the early planting, a progressive increase up to the fourth planting, a high percentage of bunt (84.3 to 93.6) up to the last planting and a substantial drop in bunt prevalence in the last planting (21.3 per cent).

Date-of-planting experiments were conducted at the Agronomy Farm near Laramie during the years 1933, 1934, and 1935. Plantings were made in rod-rows with 4 replications and at weekly intervals, as far as was possible, beginning in April or early May and

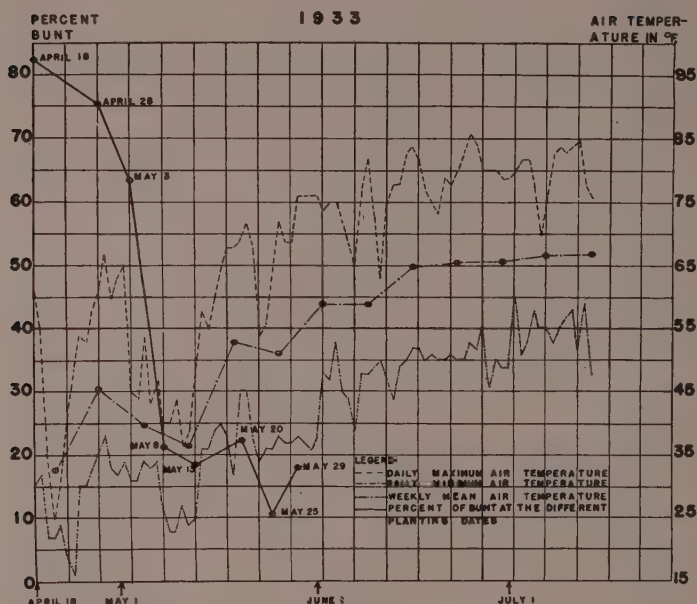


Figure 4. The relation of temperature to bunt development in the periodic plantings made in 1933.

continuing until 8 plantings had been made (6 plantings in 1935). Kota wheat, heavily coated with bunt spores previous to planting, was used throughout the experiments. The bunt inoculum (*Tilletia levis* race L-1) was collected from the local plats the previous year and used for inoculum in the tests. The wheat was planted with the special hand seeder, previously described. When necessary one or two irrigations were made during the later part of the growing season.

When the wheat was mature each row was carefully examined for the presence of bunt: The results were tabulated and the percentages of bunt were later calculated. A soil and air thermograph was used to record the temperatures of the soil at a depth of 2 inches. Because these records were not complete for the three-year period, air temperatures obtained from the official weather station at Laramie are used in the graphs to show the re-

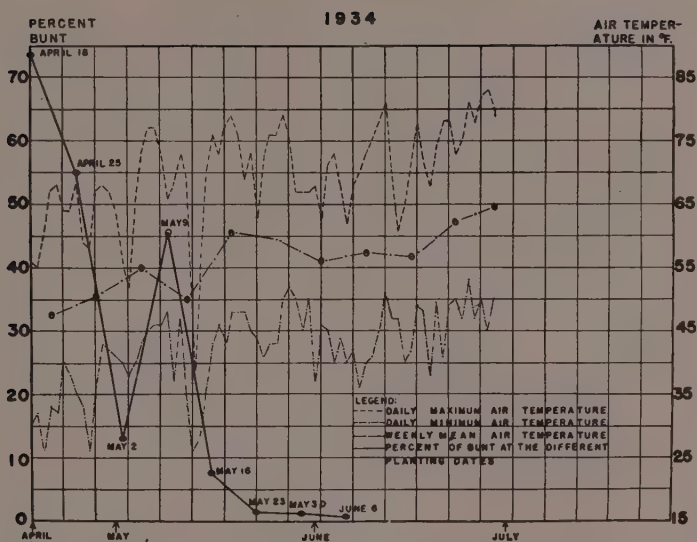


Figure 5. The relation of temperature to bunt development in the periodic plantings made in 1934.

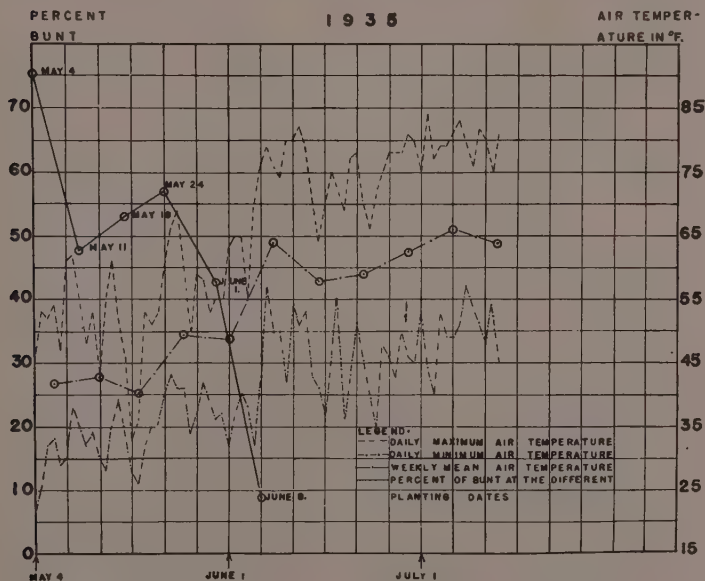


Figure 6. The relation of temperature to bunt development in the periodic plantings made in 1935.

lation of temperature and bunt. On these graphs the maximum, minimum, and average air temperatures, together with the average percentage of bunt for the different planting dates, are shown for each of the three years. Figures 4, 5, and 6 show these data for 1933, 1934, and 1935, respectively. Table II shows the bunt percentages for the different planting dates during the three years these experiments were conducted.

TABLE II

The Effect of Date of Planting on Bunt (*Tilletia levis*) Prevalence in Inoculated Kota Wheat, Planted in Four Replications at the Laramie Station in 1933, 1934, and 1935, Together with Yield Data for 1935.

DATE OF PLANTING AND PERCENTAGE OF BUNT							Yield in bushels per acre average of 4 replications
1933	Average percentage of bunt b	Average percentage of bunt	1934	Average percentage of bunt	1935	Average percentage of bunt	
April 18	70.1	94.4	April 18	73.4	May 4	75.3	6.3
April 28	64.4	85.9	April 25	54.9	May 11	48.1	10.3
May 3	47.2	80.3	May 2	13.1	May 18	52.9	8.2
May 8	13.2	30.1	May 9	45.4	May 24	56.8	6.4
May 13	6.1	31.2	May 16	7.4	June 1	42.8	7.4
May 20	3.4	41.2	May 23	1.6a	June 8	3.9	5.2
May 25	1.1	20.6	May 30	1.4a			
May 29	1.8	34.6	June 6	0.8a			
Difference required for significance	6.1	12.2		5.7		11.8	1.8

a—Soil dry; wheat germinated at about the same time.

b—This series inoculated moderately heavily with bunt spores; (seed scarcely discolored by spores), the other series in 1933 inoculated very heavily (blackening evident from presence of spores).

Table II shows that bunt was very prevalent in the early plantings when conditions were most favorable for bunt development. In most cases, there was a progressive decrease in bunt from early to late plantings. The average percentage of bunt

in the early plantings was 78.3, and in the late ones 11.5. In 1934, the planting on May 2 had relatively little bunt as compared with the planting on May 9. This may be partially accounted for by the higher temperatures after May 2, and the lower temperatures after May 9, as shown by Figure 5.

Yields were determined only in 1935 and these are low because the precipitation was light during June and later, and, also because the bunt damage was high. In this test, the second planting, made on May 11, gave the best yield because of the decided decrease in bunt as compared with the earlier planting on May 4.

THE EFFECT OF MOISTURE

Historical. Hungerford (7) in Idaho states that soil moisture is an important factor in bunt prevalence. He obtained the highest per cent of bunt infection in a soil containing 22 per cent moisture, although in preliminary work the optimum per cent soil moisture was considerably higher (8). Woolman and Humphrey (14) working in the State of Washington, report that the optimum soil moisture content for bunt development was between 16 and 30 per cent. Lungren and Durrell (9) in Colorado, state that most bunt developed at a moisture content of from 15 to 20 per cent. Heald and Gaines (5) state that low soil moisture is unfavorable to infection, while moderate moisture promotes infection.

Experimental. In the present investigation, the tests were carried out under field conditions at the Agronomy Farm, Laramie. The plats were not protected from precipitation, so that the results in some plats were modified by inopportune rains or snow. For this reason, two dates of planting were sometimes used, one early and one late, to escape, if possible, the natural moisture during the period of infection of the wheat seedlings. The experiments were laid out in 4 plats, with 16 one-rod rows per plat. Plat 1 (dry) was not irrigated at all. However, in 1934 it was necessary to supply water by sprinkling before germination of the wheat took place. In plat 2 (dry-wet), no water was applied until the wheat was about 4 inches tall, when it was irrigated from

2 to 5 times, at weekly intervals depending on the availability of water and the need for irrigation. Plat 3 (wet-dry) was irrigated weekly from 2 to 3 times until the wheat was about 4 inches tall, after which time no water was applied. Plat 4 (wet) was irrigated at weekly intervals from 3 to 8 times, depending on the availability of water and the need for irrigation. These experiments were conducted for the years 1932 to 1936, inclusive.

In 1932 two lots of Kota seed were planted in the previously described plats: One non-inoculated but containing a small amount of bunt, the other inoculated heavily with smut spores (*Tilletia levis* race L1) from a local source. These were planted on April 21 and were replicated 8 times.

In 1933 two lots of Kota seed were used. One of these was moderately inoculated with bunt spores so that the black color was scarcely discernible and the other was heavily inoculated so that the black color due to spores was very evident. The bunt (*T. levis* race L1) in both lots was of local origin. These were planted on April 25 and, likewise, replicated 8 times.

In 1934 one lot of Kota wheat was heavily inoculated with bunt (*T. levis* race L1) of local origin and planted at two dates, April 19 and May 21.

In 1935 Kota wheat was also used with three types of bunt inoculum. One lot was inoculated with bunt, (*T. levis* race L1) from the local plats as in past years; another was inoculated with bunt (*T. levis*)* from Washington and another with the other species of bunt (*T. tritici*)* also from Washington. The fourth lot was not inoculated. Because of the limited bunt inoculum secured from Washington, these lots were replicated only twice, the others 6 times. They were planted on May 4.

In 1936 the same sources of bunt were used as in 1935. However, these were planted on two dates rather than one, as in 1935. Some of the bunt inoculum was limited, sufficient for only one

*These two physiological races of bunt were kindly supplied by Dr. C. S. Holton, Wheat Investigations, Division of Cereal Crops and Diseases, Pullman, Washington. *T. levis* is race No. 4 of Dr. Gaines. *T. tritici* is the so-called Hohenheimer race, also of Dr. Gaines.

replication, while other lots were replicated from 4 to 8 times. One planting was made on May 9 and one on May 25.

When irrigation water was applied, it was allowed to run over these rod-row plats for from 2 to 3 hours so that they were

TABLE III

The Effect of Soil Moisture on the Prevalence of Bunt (*T. tritici* and *levis*) in Inoculated Kota Wheat, Planted in Four Replications at Laramie During the Period 1932-1936.

Year	Date of planting	Inoculum used	Type of irrigation				Difference required for significance
			Dry ¹	Dry-wet ²	Wet-dry ³	Wet ⁴	
			% bunt	% bunt	% bunt	% bunt	
1932	April 21	None	10.5	7.0	15.0	4.0	a
1932	April 21	<i>T. levis</i> (Wyo.)	62.2	61.2	68.2	63.2	a
1933	April 25	" " "	50.6	55.6	59.8	51.9	a
1933	April 25	" " "	70.4	73.3	87.5	76.0	a
1934d	April 19	" " "	69.7	....	....	62.5	b
1934	May 21	" " "	18.8	....	....	10.6	b
1935	May 4	" " "	47.5	58.6	54.2	65.2	11.4
1935	May 4	None ⁷	2.3	4.9	4.3	4.5	a
1935	May 4	<i>T. levis</i> ⁵	0.0	3.8	1.8	0.5	a
1935	May 4	<i>T. tritici</i> ⁶	2.3	0.0	1.4	2.0	a
1936	May 9	<i>T. levis</i> (Wyo.)	34.9	61.3	62.9	56.7	9.5
1936	May 25	" " "	26.2	62.0	56.4	62.4	7.8
1936	May 9	<i>T. levis</i> ⁵	13.1	....	....	26.9	c
1936	May 25	" " "	4.5	....	....	14.8	c
1936	May 9	<i>T. tritici</i> ⁶	15.2	....	....	14.9	c
1936	May 25	" " "	2.1	....	....	5.4	c
1936	Average of all plats		21.8	....	....	41.4	10.2

¹No irrigation water applied.

²No irrigation water applied until the wheat was approximately 4 inches tall, then irrigated from 2 to 5 times depending on the availability of water and the need for irrigation.

³Irrigated weekly (2 to 3 times) until wheat was about 4 inches tall, then water withheld.

⁴Irrigated at weekly intervals from 3 to 8 times, depending on the availability of water and the need for irrigation.

⁵Supplied by Dr. C. S. Holton, Wheat Investigations, Division of Cereal Crops and Diseases, Pullman, Washington. ⁶Gaines race No. 4. ⁷Gaines Hohenheimer race.

⁷Clean seed treated with copper carbonate.

a—Variation due to error was greater than that due to moisture.

b—The F value was smaller than that necessary to give a P of .05.

c—Inoculation sufficient for only one replication.

d—Considerable rain and snow after first planting was made, shortage of irrigation water later in the season.

thoroughly watered. Just before watering, 2 to 4 soil samples were taken in each of the dry and wet plats to determine the minimum soil moistures in the irrigated and non-irrigated plats. From an average of 22 moisture tests (surface 2 inches soil) the average minimum moisture in the irrigated plats was 9.5 per cent, with extremes of 6.1 to 16.5 per cent. After irrigation these plats had a moisture content of between 35 and 40 per cent which is the moisture-holding capacity of the soils on the basis of the dry soil weight. The non-irrigated plats were considerably drier than the minimum for the irrigated plats, averaging 5.7 per cent moisture, with extremes of 2.6 and 10.8 per cent. At the end of the growing season, all the rod-rows were carefully examined for the presence of bunt. The percentages of bunt in the different moisture series are shown in Table III, and the accompanying weather conditions in Table IV.

TABLE IV

Precipitation and Mean Temperatures for April, May, and June of the Years that Experiments Were Conducted.

	April	May	June	Total or average
1932				
Precipitation	1.89	1.80	1.63	5.32
Average temperature	38.9	49.2	56.2	48.1
1933				
Precipitation	0.95	1.03	.50	2.48
Average temperature	35.4	46.0	62.4	47.9
1934				
Precipitation	1.23	.70	.86	2.79
Average temperature	42.6	56.1	58.9	52.5
1935				
Precipitation	1.38	3.59	0.13	5.10
Average temperature	37.8	42.5	57.6	46.0
1936				
Precipitation	1.32	.46	1.93	3.71
Average temperature	40.5	52.6	61.9	51.7

Bunt was very prevalent in the plats where Kota wheat was heavily inoculated with bunt from a local source. Kota wheat apparently was not as susceptible to the physiological races secured from Washington as it was to the local race of bunt, for those bunt percentages were very low and the differences were not significant between the irrigated and non-irrigated plats. Taken as a whole, there was more bunt in the irrigated series than in the non-irrigated, the average being 37.6 and 26.9 per cent, respectively. In 1932, 1933, and 1934 none of these differences were significant, probably because of the fact that the differences in soil moisture between the irrigated and non-irrigated plats were small due to late snows and rains. In addition, temperatures in the spring of 1934 were unusually high, April being the second warmest April on record and May being the warmest May on record. However, in 1935 and 1936, the prevalence of bunt was significantly more in the irrigated than in the non-irrigated plats where local bunt was used for inoculum. Following the planting on May 4, 1935, rainfall was slight for more than a week. The planting season during 1936 was even drier, so that the differences in soil moisture were greater between the irrigated and non-irrigated plats than in 1935, and the differences in prevalence of bunt were greater also.

The average percentage of bunt was slightly greater in the *wet-dry* series (41.2 per cent) than in the *dry-wet* series (38.8 per cent), although the differences are not significant in any case.

SUMMARY AND CONCLUSIONS

Experimental work was conducted during the period, 1932 to 1936, inclusive, on the experiment farms at Laramie, Archer, and Torrington on (1) seed treatments for the control of bunt, (2) date of planting in relation to the prevalence of bunt, and (3) the effect of moisture on the prevalence of bunt.

Bunt was prevalent in nearly all of the tests, indicating that the prevailing weather was favorable for bunt development. However, seed treatments were very effective in controlling this disease.

Ceresan and formaldehyde were the most efficient in controlling seed-borne bunt, although Ceresan is to be preferred because of the danger of seed injury from formaldehyde, with resulting poor stands.

Copper carbonate (50 per cent copper) and Coppercarb (18 to 20 per cent copper) were not significantly different in effectiveness, except in one case in which the 50 per cent copper was best. Neither of the copper materials was quite as effective as Ceresan or formaldehyde.

Time of planting is very important on the subsequent development of bunt. There was an average of 78.3 per cent bunt in the early plantings. In subsequent plantings, there was, in general, a progressive decrease in percentage of bunt with an average of 11.5 per cent in the late plantings. Thus, temperature appears to be a very important factor in the development of bunt.

More bunt developed, in general, in the irrigated than in the non-irrigated plats. The bunt averaged 37.6 per cent in the former and 26.9 per cent in the latter, although in some years the differences were not significant, probably because of rains and late snows which kept the soil unusually moist during the early growing season.

There was but little evidence of bunt as a result of soil infestation, although in 1935 there appeared to be some.

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